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For: INTELLIGENT PICONET FORMING

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Sir:

It is respectfully requested that this application be given the benefit of the foreign filing date under the provisions of 35 U.S.C. §119 of the following, a certified copy of which is submitted herewith:

Application No.	Country of Origin	Filed
99850193.6	EP	6 December 1999

Respectfully submitted,

NIXON & VANDERHYE P.C.

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By: [signature]
H. Warren Burnam, Jr.
Reg. No. 29,366

TECHNOLOGY CENTER 1700

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HWB:lsh
1100 North Glebe Road, 8th Floor
Arlington, VA 22201-4714
Telephone: (703) 816-4000
Facsimile: (703) 816-4100

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Bescheinigung | Certificate | Attestation

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The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

99850193.6

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
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Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

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TELEFONAKTIEBOLAGET LM ERICSSON
126 25 Stockholm
SWEDEN

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Intelligent Piconet Forming

FIELD OF THE INVENTION

The invention is mainly related to the problem of forming ad-hoc wireless networks and more particularly to the wireless technology Bluetooth and how a Bluetooth device may best discover masters in existing piconets and connect as a slave to those masters without having to use the master-slave switch.

RELATED ART

Bluetooth is a relatively new specification for wireless communication of data and voice based on a low-cost short-range radio link. It can be built into a 9x9mm microchip which facilitates ad-hoc connections for both stationary and mobile communication environments. Information in the present application is based in part on the Bluetooth specification, "Specification of the Bluetooth System", July 26th 1999, the entirety of which is hereby incorporated by reference.

The original intention of Bluetooth was to eliminate cables between phones, PC-cards, wireless headsets, etc., but today Bluetooth is a true ad-hoc wireless network technology intended for both synchronous traffic, e.g. voice, and asynchronous traffic, e.g. IP based data traffic. The aim is that any commodity device such as telephones, PDAS, laptop computers, digital cameras, video monitors, printers, fax machines, etc. should be able to communicate over the radio interface, i.e. any of these devices could have contain a Bluetooth radio chip and its software.

Beyond merely replacing the cables between various devices, Bluetooth technology will provide a bridge to existing data networks, a peripheral device, and a mechanism to form small

private ad-hoc groupings of connected devices away from fixed network infrastructures or connected to a fixed infrastructure via a gateway. Bluetooth radio uses a fast acknowledgement and frequency hopping scheme to make the link robust. The radio modules avoid interference with one another by hopping to a new frequency after transmitting or receiving a packet. Compared with other systems operating in the same frequency band, the Bluetooth radio typically hops faster and uses shorter packets. The radio band used by Bluetooth is the unlicensed 2.4 GHz ISM (Industrial-Scientific-Medical) band with a channel spacing of 1 MHz.

The Bluetooth system consists of a radio unit, a link control unit, and a support unit for link management and host terminal interface function. The system provides a point-to-point connection (only two Bluetooth (BT) units involved), or a point-to-multipoint connection. In the point-to-multipoint connection, the channel is shared among several BTs. Two or more Bluetooth (BT) units sharing the same channel form a *piconet* (see Figure 1). Within a piconet a BT unit can have either of two roles: master or slave. Within each piconet there may be only one master (and there must always be one) and one (Figure 1(a)) slave or more than one (Figure 1(b)), up to seven active slaves. Any BT unit can become a master in a piconet.

Furthermore, two or more piconets can be interconnected, forming what is called a *scatternet* (see Figure 1(c)). The connection point between two piconets consists of a BT unit that is a member of both piconets. A BT unit can simultaneously be a slave member of multiple piconets, but only master in one (although a BT unit that acts as master in one piconet can participate in other piconets as a slave). A BT unit can only transmit and receive data in one piconet at a time, so participation in multiple piconets has to be on a time division multiplex basis.

The Bluetooth system provides full-duplex transmission built on slotted Time Division Duplex (TDD), where each slot is 0.625 ms long. The time slots are numbered sequentially using a very large number range (cyclic with a cycle of 2^{27}). Master-to-slave transmission always starts in an even-numbered time slot while slave-to-master transmission always starts in an odd-numbered time slot. An even-numbered time slot and its subsequent odd-numbered time slot (i.e. a master-to-slave time slot and a slave-to-master time slot, except when multi-slot packets are used) together are called a *frame*. There is no direct transmission between slaves, either within a Bluetooth piconet or between two different piconets.

The communication within a piconet is organised such that the master polls each slave according to some polling scheme. With one exception a slave is only allowed to transmit after having been polled by the master. The slave will then start its transmission in the slave-to-master time slot immediately following the packet received from the master. The master may or may not include data in the packet used to poll a slave. The only exception to the above principle is that when a slave has an established Synchronous Connection Oriented (SCO) link it is always allowed to transmit in the pre-allocated slave-to-master time slot, even if not explicitly polled by the master in the preceding master-to-slave time slot.

Each BT unit has a globally unique 48 bit IEEE 802 address. This address, called the Bluetooth Device Address (BD_ADDR) is assigned when the BT unit is manufactured and it is never changed. In addition to this, the master of a piconet assigns a local Active Member Address (AM_ADDR) to each active slave member of the piconet. The AM_ADDR, which is only three bits long, is dynamically assigned and de-assigned and is unique only within a single piconet. The master uses the AM_ADDR when polling a slave in a piconet. However, when the slave, triggered by a packet from the master addressed with the

slave's AM_ADDR, transmits a packet to the master, it includes its own AM_ADDR (not the master's) in the packet header. An AM_ADDR for the master is not included since it does not exist. The master of a piconet never assigns an AM_ADDR to itself.

Even though all data is transmitted in packets, the packets can carry both synchronous data, on Synchronous Connection Oriented (SCO) links (mainly intended for voice traffic), and asynchronous data, on Asynchronous Connectionless (ACL) links. The SCO link is a symmetric point-to-point link between the master and a specific slave. The SCO link reserves slots and can therefore be considered as a circuit-switched connection between the master and the slave. The ACL link is a point-to-multipoint link between the master and all the slaves participating on the piconet. In the slots not reserved for SCO links, the master can establish an ACL link on a per slot basis to any slave. The ACL link provides a packet-switched connection between the master and all active slaves participating in the piconet.

Depending on the type of packet that is used, an acknowledgement and retransmission scheme is used (not for SCO packets transferring synchronous data) to ensure reliable transfer of data. Forward error correction (FEC) in the form of channel coding is also used which limits the impact of random noise on long-distance links.

The standard format of a Bluetooth packet (although there are exceptions for certain control packets) is shown in Figure 2. The access code and header are of fixed size, 72 bits and 54 bits, respectively. The payload can range from zero to a maximum of 2745 bits. The AM_ADDR is located in the packet header followed by some control parameters (e.g. a bit indicating acknowledgement or retransmission request of the

previous packet, when applicable) and a header error check (HEC).

The Access Code in the packet can be of three different types:

- Channel Access Code (CAC)
- Device Access Code (DAC)
- Inquiry Access Code (IAC)

The Channel Access Code identifies a channel that is used in a certain piconet, i.e. in essence the Channel Access Code identifies the piconet. All packets exchanged within a piconet carry the same Channel Access Code. The Channel Access Code is derived from the BD_ADDR of the master unit of the piconet. The Device Access Code is derived from a BD_ADDR of a particular BT unit. It is used for special signalling procedures, e.g. the PAGE procedure. The Inquiry Access Code comes in two variants: the General Inquiry Access Code (GIAC) and the Dedicated Inquiry Access Code (DIAC). Both are used in the INQUIRY procedure, explained in more detail below.

The format of the payload depends on the type of packet. The payload of an ACL packet consists of a header, a data field and, with the exception of AUX1 type packets, a cyclic redundancy check (CRC). The payload of an SCO packet consists of only a data field. In addition there are hybrid packets including two data fields, one for synchronous data and one for asynchronous data. Packets in which the payload does not include a CRC are neither acknowledged nor retransmitted.

The protocol layers of a Bluetooth system are illustrated in Figure 3. The Baseband, LMP and L2CAP represent existing Bluetooth specific protocols. The "High level protocol or application" layer represents protocols that may or may not be Bluetooth specific while the Network layer is currently not specified in the Bluetooth standard.

A limitation of the Bluetooth system is that in the current standard specifications there is no way to address and route packets from one piconet to another. How inter-piconet communication is performed in a scatternet is not specified, although there are proposals for how to achieve this.

An important capability in any ad-hoc networking technology is the *neighbour discovery* feature. This is true also for Bluetooth. Without a neighbour discovery capability a BT unit would not be able to find any other BT units to communicate with and consequently no ad-hoc network would be formed. The neighbour discovery procedure in Bluetooth consists of the INQUIRY message and the INQUIRY RESPONSE message. An "inquiry" procedure is defined which is used in applications where the destination's device address is unknown to the source. One can think of e.g. public facilities like printers or facsimile machines. Alternatively, the inquiry procedure can be used to discover which other Bluetooth units are within range.

A BT unit wanting to discover neighbouring (i.e. within radio coverage) BT units will transmit repeatedly, according to well specified timing and frequency sequences, INQUIRY messages and listen for INQUIRY RESPONSE messages, which are optional. An INQUIRY message consists of only an Inquiry Access Code. It does not contain any information about the source but may indicate which class of devices should respond. The Inquiry Access Code can be a General Inquiry Access Code (GIAC), which is sent to discover any BT unit in the neighbourhood, or a Dedicated Inquiry Access Code (DIAC), which is sent to discover only a certain type of BT units, for which a particular DIAC is dedicated.

A BT unit receiving an INQUIRY message (including the GIAC or an appropriate DIAC) may respond with an INQUIRY RESPONSE message. The INQUIRY RESPONSE message is really an FHS (Frequency Hop Synchronisation) packet (see Figure 4). The FHS

is a special control packet revealing, among other things the Bluetooth device and the clock of the sender. The payload consists of eleven fields. All fields in the packet, except the AM_ADDR field (and the "Undefined" field of course) indicate properties or parameters of the BT unit that sends the FHS packet. The LAP (Lower Address Part), UAP (Upper Address Part) and NAP (Non-significant Address Part) fields together comprise the BD_ADDR. The "Class of device" field indicates the class of device of the BT unit. The CLK field contains the current value of the BT unit's internal clock. The SR, SP and "Page scan mode" fields are all control parameters concerning the PAGE procedure. The AM_ADDR field can be used to assign an AM_ADDR to a BT unit becoming a slave in a piconet, otherwise the three bits should all be set to zero. The "Undefined" field consists of two bits, reserved for future use, which should be set to zero. This will be significant in the present invention.

An FHS packet is also used for other purposes in a Bluetooth system in addition to the INQUIRY RESPONSE, e.g. for synchronisation of the frequency hop channel sequence (that is where its name comes from), a page master response and in the master-slave switch. By listening for INQUIRY RESPONSE messages the BT unit that initiated the INQUIRY procedure can collect the BD_ADDR and internal clock values of the neighbouring BT units.

Related to the INQUIRY procedure is the PAGE procedure, which is used to establish an actual connection between two BT units. Once the BD_ADDR of a neighbouring BT unit is known (as a result of an INQUIRY procedure) the neighbouring BT unit can be paged with a PAGE message. Also knowing the internal clock value of the BT unit to be paged will potentially speed up the PAGE procedure, since this makes it possible for the paging unit to estimate when and on what frequency hop channel the neighbouring BT unit will listen for PAGE messages.

A PAGE message consists of the Device Access Code (DAC), derived from the BD_ADDR of the paged BT unit. A BT unit receiving a PAGE message including its own DAC responds with an identical packet (i.e. including only the DAC of the paged BT unit). The paging BT unit then replies with an FHS packet, including the BD_ADDR of the paging BT unit, the current value of the internal clock of the paging BT unit, the AM_ADDR assigned to the paged BT unit and some other parameters (see Figure 4). The paged BT unit then responds once again with its DAC and thereby the connection between the two BT units is established.

If the paging BT unit already was the master of a piconet, the paged BT unit has now joined this piconet as a new slave unit. Otherwise, the two BT units have just formed a new piconet with the paging BT unit as the master unit. Since the INQUIRY message does not include any information about its sender (in particular not its BD_ADDR), the BT unit that initiated the INQUIRY procedure is the only one that can initiate a subsequent PAGE procedure. Thus, the BT unit initiating an INQUIRY procedure will also be the master of any piconet that is formed as a result of a subsequent PAGE procedure. However, if considered necessary, the roles of master and slave can be switched using the master-slave-switch mechanism in Bluetooth. This, however is a complex and extensive procedure resulting in a redefinition of the entire piconet, involving also all other slave units in the piconet.

The INQUIRY and PAGE procedures are well specified in the current Bluetooth standard. These are all the tools that are needed to form a new Bluetooth piconet or to join an existing one. However, even though the tools as such are well specified, there are no rules or guidelines as to how to use them. When neighbours are discovered there is no way to know who to connect to in order to form an appropriate piconet. And even if the master-slave-switch mechanism exists, using it is

an extensive procedure and it is hard to know when to use it in order to improve the efficiency of a piconet. Hence, piconets will more or less form at random, often resulting in far from optimal piconet and scatternet structures.

An exception is when the BT unit wishing to establish a connection already knows the BD_ADDR of the BT unit it wants to connect to. The use of the Dedicated Inquiry Access Code in the INQUIRY messages and the Class of device field in the FHS packet (indicating the class of device of the BT unit that sends the FHS packet) can also be used to impose a certain control of the forming of piconets. However, to a large extent, the BT units forming a piconet or a scatternet will be groping in the dark.

The piconet and scatternet forming procedures would be facilitated and better piconet and scatternet topologies would be possible to achieve, if more information about the involved BT units could be exchanged before the piconets and scatternets are actually established. For this purpose the present intention introduces simple mechanisms for exchanging small, but valuable, pieces of information during the INQUIRY and PAGE procedures and a simple mechanism to increase the control of the forming of piconets and scatternets, based on the exchanged information.

Since Bluetooth is the main target, the invention will be described in a Bluetooth context using Bluetooth terminology. However, it will also be briefly described how the intention can be generalised to be applicable to other ad-hoc network technologies.

The information exchanged during the INQUIRY and PAGE procedures is not enough to determine how to establish connections in order to form an efficient piconet. Furthermore, the fact that the BT unit that initiates an INQUIRY procedure will have to be the master of any piconet

that forms as a result of a subsequent PAGE procedure makes the forming of piconets and scatternets inflexible. The complex and extensive master-slave-switch mechanism is not enough to compensate for this inflexibility.

Consider, for instance, a scenario where a number of people have gathered in a conference room for a meeting. They turn on their Bluetooth laptops, which at random start to send INQUIRY messages and listen for INQUIRY messages from other BT units. Some other people may also join the meeting a bit late resulting in more INQUIRY procedures. The result of these random INQUIRY procedures(followed by PAGE procedures and the forming of piconets) may well be something like what is shown in Figure 5, while an optimal piconet structure could be similar to what is shown in Figure 6.

When a new BT unit moves into the neighbourhood of an existing piconet, e.g. like in this meeting scenario, it may want to communicate with the BT units connected to that piconet. What the BT unit would like to do then is to join the piconet as a new slave unit. However, the means by which to achieve this provided by the current Bluetooth specifications are few and inefficient. The BT unit would have to wait and hope to be discovered by the master unit of the piconet, with an INQUIRY message from the master unit, and subsequently paged and connected. However, when receiving an INQUIRY message, this does not provide any information about the sender. So an INQUIRY message received by the BT unit may also be from a slave unit (which is actually more likely, since there are more slave units).

In any case waiting and hoping is not an efficient method, but the current Bluetooth standard allows an alternative way. The BT unit itself can send INQUIRY messages and hope to receive a response from the master unit of the piconet. But the INQUIRY RESPONSE message (an FHS message) does not tell its receiver

whether the sender is a master of a piconet or not. So the BT unit has to take a chance and page and connect to a responding BT unit, hoping that the responding BT unit turns out to be the master of the piconet. If the BT unit is lucky, and actually manages to connect to the master unit of the existing piconet, a new piconet is formed with the inquiring (and paging) BT unit as the master unit and the paged master unit (of the already existing piconet) as a slave unit.

To actually join the old piconet the newly arrived BT unit has to request a master-slave switch. This master-slave switch will make the master unit of the old piconet (which is also a slave unit of the new piconet) master also in the new piconet. Then, per definition (since the Channel Access Code identifying the piconet is derived from the master unit's BD_ADDR), the two piconets will merge into one, making the new BT unit a slave unit in the merged piconet. Hence, joining an existing piconet as a slave unit requires first of all luck, and possibly also a master-slave switch. Accordingly, something more is needed than the existing "wait and hope" and "chance connection" methods as specified.

SUMMARY OF THE INVENTION

The invention is mainly related to the problem of forming ad-hoc wireless networks and more particularly to the wireless technology Bluetooth and how a Bluetooth device may best discover masters in existing piconets and connect as a slave to those masters without having to use the master-slave switch.

As can be seen above, there still exists disadvantages with the current methods of forming ad-hoc networks in the Bluetooth system. A Bluetooth unit cannot easily discover which other BT units exist as neighbouring masters or slaves. There is also a problem in joining as a slave without using the master-slave switch.

Accordingly, it is an object of the present invention to provide a method to more easily find out the roles (master or slave) of the neighbouring BT units to a particular BT unit, i.e. whether the neighbouring BT units are masters or slaves in existing piconets. In addition, a method is presented which allows the BT unit to connect a master as a slave without using the complicated master-slave switch. The inventive solution can be divided into two basic parts.

First, a few additional small, but vital, pieces of information are exchanged between two BT units during the INQUIRY procedure. This provides some information about the responding BT unit's status in existing piconet(s), which facilitates the decision of what BT unit to attempt to connect. A similar improvement of the INQUIRY procedure can be achieved in an alternative way, by using a modified INQUIRY message. These two alternatives, which are the first part of the solution, are described in further detail below.

In the second part of the invention a new mechanism is introduced by which the initial inquiring and paging BT unit can become a slave unit in a newly formed piconet or in an already existing piconet. This new mechanism is used during the PAGE procedure and hence the use of the complex and extensive master-slave-switch mechanism is avoided, although there may of course be other situations when the master-slave-switch mechanism is still needed. This second part of the solution is also described in further detail below.

Some merits of the invention include providing means to impose an intelligent control of the forming of piconets in general. Efficient mechanisms are presented which enable a BT unit to join an existing piconet. In addition the present invention enables exchange of piconet related information during the INQUIRY procedure and enhances the INQUIRY procedure so that master units of existing piconets can be discovered. The

second part of the invention provides a mechanism by which the initially inquiring and paging BT unit can become a slave unit in a newly formed or previously existing piconet without going through the master-slave switch procedure. Furthermore, the inventive solution can be used to facilitate reforming of scatternet structures.

The preferred procedures of the invention do not imply modifications of any of the existing Bluetooth message formats although some of the alternative procedures require modifications of existing message formats.

Although the preferred embodiments of the present invention are directed to a Bluetooth system, the ideas presented are also applicable to general ad-hoc networks which have similar features as Bluetooth. The present invention provides means to impose an intelligent control of the forming of ad-hoc networks in general and enables exchange of ad-hoc network related information during the neighbour discovery procedure. A mechanism is provided for the unit initiating the establishment of an ad-hoc network to transfer the specific role of the initiator to another unit during the establishment phase.

Although the invention has been summarised above, the method according to the present invention is defined according to appended claims 1, 3, 18, 19, 22, 28, 29, 30 and 31. Various embodiments are further defined in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described in more detail with reference to preferred embodiments of the present invention, given only by way of example, and illustrated in the accompanying drawings, in which:

FIG. 1 is a diagram of various master-slave relationships in a Bluetooth system.

FIG. 2 is a diagram of a standard Baseband packet format.

FIG. 3 is a diagram of the Bluetooth protocol layers.

FIG. 4 is a diagram of an FHS packet.

FIG. 5 is a diagram of a suboptimal piconet and scatternet structure.

FIG. 6 is a diagram of an optimal piconet structure.

FIG. 7 is a flowchart showing the combined procedures of both parts of the present invention.

FIG. 8 shows an alternate flowchart of the combined procedures of both parts of the present invention.

DETAILED DESCRIPTION

The first part of the present invention allows a Bluetooth unit to discover whether a neighbouring Bluetooth unit is connected to an existing piconet and, in such case, whether it is connected as a master or as a slave. In particular, the present invention allows a Bluetooth unit to discover a master in an existing piconet. Several alternative solutions are presented which improve on the procedures in the Bluetooth specification, as discussed above.

The FHS packet, which is used as the INQUIRY RESPONSE message (and in other procedures as well), includes some information about the sending BT unit, but none about the piconet the BT unit may be connected to, or even the BT unit's status in such a piconet. Including such information would give the inquiring BT unit some essential background knowledge to be used when the BT unit decides what other BT unit to attempt to connect.

A very basic piece of information is whether the responding BT unit is a master of an existing piconet or not. The importance of this piece of information is illustrated by the meeting

scenario described above. This can be coded using one of the two undefined (reserved for future use) bits in the FHS packet, as shown in Figure 4. Preferably, setting the bit to one would mean that the sending BT unit is the master of a piconet, while setting the bit to zero would mean that the sending BT unit is not the master of a piconet.

The piconet related information in the FHS packet can be extended by using also the second of the two undefined bits. This can be used to indicate whether the sending BT unit is a slave unit in at least one piconet. Preferably, setting the bit to one would mean that the sending BT unit is a slave unit in one or more piconet(s), while setting the bit to zero would mean that the sending BT unit is not a slave unit of any piconet at all.

Hence, we get the following four possible combinations of the two bits (in this illustration the right bit indicates the "master status" and the left bit indicates the "slave status" of the sending BT unit):

00 The sending BT unit is not connected to a piconet or the sending BT unit does not support this use of the "Undefined" field.

01 The sending BT unit is the master unit of a piconet.

10 The sending BT unit is a slave unit in one or more piconet(s).

11 The sending BT unit is the master unit of one piconet and a slave unit in one or more other piconet(s).

Backwards compatibility with the current Bluetooth specification is achieved with this solution, since the current specification of the FHS packet states that the two undefined bits should be set to zero. This would indicate that

the sending BT unit is not connected to any piconet, which is "harmless" information.

An alternative way to include this information in the FHS packet is to use the *Class of device* field as shown in Figure 4. The current specification allows for alternative codings of a part of the *Class of device* field. A new coding of this part of the *Class of device* field could be used to include the above information (and possibly also other useful piconet (and scatternet) related information).

Yet an alternative way to include this information in the FHS packet is to use the AM_ADDR field. According to the current specification of the FHS packet the three bits of the AM_ADDR field should be set to zero, when the FHS packet is used as an INQUIRY RESPONSE message, since assigning an AM_ADDR is not applicable in that case. Therefore, these three bits are available to code other information, e.g. piconet related information. By using the AM_ADDR field eight different states could be coded instead of the four states coded with the undefined bits. It would also be possible to use both the undefined bits and the AM_ADDR field to code piconet related (or other) information, resulting in five bits which translates to 32 possible states. In the following discussion it will be assumed that only the three bits of the AM_ADDR field is used for this purpose, while the two undefined bits are still undefined, unless explicitly stated otherwise. Two of the three bits in the AM_ADDR field could be used to code exactly the same information as suggested for the two undefined bits above. The third bit could be used to indicate whether the sending BT unit, when subsequently being paged, will want to connect to the paging unit as a slave unit or as a master unit (using the modified PAGE procedure according to the present invention as described below).

A reason for not wanting to become a master unit when subsequently being paged may e.g. be that the BT unit is already the master unit of a piconet with seven active slave units, giving no room for yet another active slave unit. Preferably, setting the third bit to one would indicate that the sending BT unit prefers to have the role of the master unit after a subsequent (modified) PAGE procedure, while setting the third bit to zero would indicate a preference for the slave role. This coding provides backwards compatibility with the current Bluetooth specification since, according to the current specification of the FHS packet, the three bits of the AM_ADDR field should be set to zero when the FHS packet is used as an INQUIRY RESPONSE message. The following are the resulting possible combinations of the three bits of the AM_ADDR field (in this illustration the right-most bit indicates the "master status" and the middle bit indicates the "slave status" and the left-most bit indicates the "role preference" of the sending BT unit):

000 The sending BT unit is not connected to a piconet and prefers to be a slave unit after a subsequent PAGE procedure or the sending BT unit does not support this use of the AM_ADDR field.

001 The sending BT unit is the master unit of a piconet and prefers to be a slave unit after a subsequent PAGE procedure.

010 The sending BT unit is a slave unit in one or more piconet(s) and prefers to be a slave unit after a subsequent PAGE procedure.

011 The sending BT unit is the master unit of one piconet and a slave unit in one or more other piconet(s) and prefers to be a slave unit after a subsequent PAGE procedure.

100 The sending BT unit is not connected to a piconet and prefers to be a master unit after a subsequent (modified) PAGE procedure.

101 The sending BT unit is the master unit of a piconet and prefers to be a master unit after a subsequent (modified) PAGE procedure.

110 The sending BT unit is a slave unit in one or more piconet(s) and prefers to be a master unit after a subsequent (modified) PAGE procedure.

111 The sending BT unit is the master unit of one piconet and a slave unit in one or more other piconet(s) and prefers to be a master unit after a subsequent (modified) PAGE procedure.

If the AM_ADDR field is used for coding of piconet related information in combination with the above described use of the two undefined bits, the AM_ADDR field could e.g. be used to indicate the number of active slave units in the piconet for which the sending BT unit is the master unit (provided that the two undefined bits indicates that the BT unit is the master unit of a piconet (i.e. codes "0 1 " or " 1 1 " as defined above). The number of slave units in the piconet can be encoded in the AM_ADDR field as an ordinary binary number. Since this field has 3 bits it can encode the number of slave units in the piconet, which may be a maximum of seven. Setting the three bits to zero would mean that no information about the number of active slave units is available. Also when the undefined bits indicate that the sending BT unit is not the master unit of a piconet (i.e. codes "00" or "10" as defined above) the three bits of the AM_ADDR field should be set to zero. This use of the all-zero AM_ADDR field provides backwards compatibility with the current Bluetooth specification, since the current specification of the FHS packet states that these three bits should be set to zero when

the FHS packet is used as an INQUIRY RESPONSE message. The resulting combinations of the two undefined bits and the three bits of the AM_ADDR field when used in the way described in this paragraph are listed in Table 1.

The two undefined bits.	**The meaning of the two undefined bits.**	**The AM_ADDR field.**	**The meaning of the 3 bits of the AM_ADDR field.**
00	The sending BT unit is not connected to a piconet.	000	This combination should be used
		001-111	These combinations should not be used.
01	The sending BT unit is the master of a piconet.	000	No info available about slave units.
		001-111	The number of active slave units in the piconet.
10	The sending BT unit is a slave unit in one or more piconet(s).	000	This combination should be used.
		001-111	These combinations should not be used.
11	The sending BT unit is the master of one piconet and slave in one or more other piconet(s).	000	No info available about slave units.

		001-111	The number of active slave units in the piconet in which the sending BT unit is the master unit.

Table 1 combinations of the two undefined bits and the three bits of the AM_ADDR field.

When an INQUIRY RESPONSE message is received indicating that the sending BT unit is a slave unit in one or more piconet(s) (i.e. code "10" of the undefined bits above), it would be very useful if the BD_ADDR of the master unit of the responding BT unit's piconet (or even multiple master unit BD_ADDRs if the responding BT unit is connected to more than one piconet) could be retrieved. A retrieved master unit BD_ADDR could be used to page the master unit, preferably using the modified PAGE procedure according to the present invention as described below, which lets the paging BT unit join an existing piconet without performing a master-slave switch. Since there are not enough available bits to code a BD_ADDR in the FHS packet, another method would have to be used to retrieve the information.

It should be pointed out that the information coded by the two undefined bits in the FHS message, in the Class of Device field, or by the three bits of the AM_ADDR field in the FHS packet are not the only ones possible. Useful information which may be encoded (in an FHS packet or in a modified PAGE RESPONSE message as described below) in the present invention include e.g.:

(1) whether the sending BT unit is connected to a piconet or not,

(2) whether the sending BT unit is a master or a slave(s) or both,

(3) whether the sending BT unit prefers to be a master or a slave unit after the subsequent PAGE procedure,

(4) the number of slaves in a piconet,

(5) the BD_ADDR(s) of the master(s) of the existing piconet(s) in which the sending BT unit is a slave member,

(6) the clock values (as estimated by the sending BT unit) of the master unit(s) of the existing piconet(s) in which the sending BT unit is a slave member,

(7) inter-piconet scheduling parameters,

(8) battery status,

(9) traffic parameters, or

(10) priority parameters.

The inquiring BT unit or units can use this information when making the decision as to which unit it should make a connection or connections to.

If the available bits in the FHS packet are not enough to encode the information to be transferred, another method has to be used. One possibility is to use a modified PAGE procedure, where the paging unit indicates in the PAGE message that the intention of the paging procedure is not to establish a connection, but to retrieve useful information (as outlined above) e.g. one or multiple master unit BD_ADDR(s) (of the master unit(s) of the piconet(s) to which the paged BT unit is connected as a slave unit). The paged BT unit would then respond with a new type of PAGE RESPONSE message, or with the regular one (i.e. a packet consisting of only the Device

Access Code of the responding BT unit) extended with the requested information, e.g. BD_ADDR(s) in this example. In the case of master BD_ADDR(s) being requested, possibly the response message could also include the current clock value of the master unit (or each of the master units if multiple master units are indicated), as estimated by the responding slave unit, to facilitate the subsequent paging of a master unit. The indication in the modified PAGE message could be e.g. a single bit extension indicating that all available information is requested or a multiple bit extension indicating the request of relevant subsets of the available information.

Another method for a BT unit to discover master units (of already existing piconets) in the vicinity would be to introduce a new Dedicated Inquiry Access Code (DIAC). Only BT units that are master units would respond to an INQUIRY message including such a "master DIAC". A BT unit that is not a master unit would discard the INQUIRY message. The "intended-only-for-master-units" indication could also be an extension or modification of the currently existing Inquiry Access Codes (IACs). Then all the existing IACS, the General Inquiry Access Code (GIAC) as well as the Dedicated Inquiry Access Codes (DIACs), could carry an additional indication that the INQUIRY message is intended only for master units. A GIAC carrying this indication would be intended for all master units, while a DIAC carrying the indication would be intended for the master units of the BT unit type for which the DIAC is dedicated. This method using modified Inquiry Access Codes in the INQUIRY message may well be combined with the other methods previously described.

The above described DIAC method could be extended to include the use of new DIACs, as DIACs of their own or, as described above, as extensions or modifications to existing DIACs and the existing GIAC. Such other new DIACs (or DIAC/GIAC

extensions/modifications) could be DIACs dedicated for BT units with a certain status. A BT unit with this certain status could be e.g.

- a BT unit being a slave unit in one and only one piconet,

- a BT unit being a slave unit in at least one piconet,

- a BT unit being a slave unit in more than one piconet,

- a BT unit being a slave unit in one or more piconets, but a master unit in none,

- a BT unit being a slave unit in one or more piconets and a master unit in one piconet,

- a BT unit being a master unit in one piconet, but a slave unit in none,

- a BT unit that is not connected to any piconet,

- a BT unit with low current traffic load,

- a BT unit with high current traffic load.

This list is of course not exhaustive, but also other types of status could be associated with new DIACs (or DIAC/GIAC extensions/modifications). Only BT units that have the particular status indicated by a certain DIAC (or GIAC extension/modification) would respond to an INQUIRY message including this DIAC (or GIAC extension/modification). Alternatively, if the particular status is indicated by an extension or modification to an existing DIAC, only the BT units of the type indicated by the DIAC, which also have the status indicated by the extension or modification, would respond to an INQUIRY message carrying this extended of modified DIAC.

The preferred alternative in this part of the present invention is to use the four combinations of the two undefined bits of the FHS packet to convey information about the sending BT unit's status in existing piconets, possibly combined with the method using the new "master DIAC".

Once the BT has discovered the masters in neighbouring piconets as outlined above it may want to connect to a master as a slave without the problems associated with the master-slave switch mechanism. The method of connecting is the focus of the second part of the invention as outlined below.

Using the first part of the invention outlined above the BT is able to discover a master unit of an already existing piconet. The master unit is discovered when an INQUIRY RESPONSE message, indicating that the responding BT unit is a master unit (using a new indication in the FHS packet or simply by responding to an INQUIRY message dedicated for master units), is received, possibly along with a number of INQUIRY RESPONSE messages from slave units. The BD_ADDR of a master unit can also have been retrieved from a slave unit in the same piconet using the modified PAGE procedure described in the previous section.

When a BT unit has discovered a master unit (of an already existing piconet), the BT unit may want to connect to this master unit as a slave. If the discovered master unit has indicated that it prefers to be a slave unit after a subsequent PAGE procedure (provided that this type of indication, as previously outlined, is used) the BT unit may choose to: (1) still try to connect to the master unit as a slave unit, (2) try to connect to the master unit as a master unit (thereby not joining the piconet of the discovered master unit, but making the discovered master unit a slave unit in a piconet where the BT unit is the master unit), or (3) refrain from paging the discovered master unit. To be able to do this

without performing a master-slave switch a new mechanism is required. For this purpose the following modified PAGE procedures according to the present invention are introduced.

Just as with the regular PAGE procedure the modified procedure according to the present invention begins with a PAGE message, consisting of only the DAC of the paged BT unit, followed by an identical response package from the paged BT unit. The difference compared with the known method is that in the subsequent FHS packet from the paging BT unit an indication is included, indicating that the paging BT unit actually wants to be paged by the currently paged BT unit. One of the two undefined bits in the FHS packet could be used for this indication. Please note that using the same two undefined bits in the FHS packet for something else in the second part of the solution than in the first part of the solution is not a contradiction. It is quite possible to specify the meaning of the two bits as situation dependent, e.g. one meaning when used in the INQUIRY procedure and another meaning when used in the PAGE procedure.

Preferably, to provide backwards compatibility with the current Bluetooth specification which states that the two undefined bits should be set to zero, the bit should be set to one when indicating that a reversed paging direction is requested. The three bits of the AM_ADDR in an FHS packet indicating a request of reversed paging direction should be set to zero. Actually, an alternative way to include the indication would be to simply let the all-zero AM_ADDR indicate a request of reversed paging direction when the FHS packet is used in the PAGE procedure. The two undefined bits would then still be undefined or could be used to code the same piconet related information as described in first part of the invention where a master in a neighbouring piconet is found.

When a request for a reversed paging direction is received in a BT unit being paged, there are two alternative ways to handle the reversal of the paging direction: (1) the current PAGE procedure is terminated, immediately followed by a new one initiated by the previously paged BT unit, or (2) the paging direction is immediately reversed (without termination) by letting the BT unit receiving the request for reversed paging direction send an FHS packet (with all parameters set as if the sender is the paging BT unit) to the BT unit sending the request. In the former case the new PAGE procedure (in the reversed direction) proceeds just as a regular PAGE procedure. In the latter case the BT unit receiving the second FHS packet (i.e. the BT unit requesting the reversal of the paging direction) responds with a packet including only the BT unit's DAC (i.e. just as the final message of the regular PAGE procedure) thereby concluding the reversed PAGE procedure.

If the initially paged BT unit in the above two cases does not accept a reversal of the paging direction (e.g. because it already is a master unit and can not accept any more slave units in its piconet) this is indicated to the paging BT unit by responding to the FHS packet with a second FHS packet including the same indication of request for reversal of the paging direction, i.e. with the relevant (previously undefined) bit set or with the AM_ADDR field set to all zeros or both. The BT unit receiving this indication of that the reversal of the paging direction is not accepted (i.e. the BT unit that initiated the PAGE procedure) can then choose to either proceed with the PAGE procedure without reversing of the direction or abandon the PAGE procedure. If it chooses to proceed, this can be done in two alternative ways: (1) by restarting the PAGE procedure by sending a new initial PAGE message or (2) by sending a third FHS message (in the initial direction), this time without the indication of request for reversal of the paging direction.

An alternative procedure for reversal of the paging direction could be to let the initial PAGE message carry the indication of the request for reversal of paging direction. Since the reversal of the paging direction requires that the BD_ADDR or the DAC of the BT unit initiating the PAGE procedure be transferred to the initially paged BT unit, it is preferable that the indication consists of the BD_ADDR or the DAC of the sending BT unit. In this alternative the actual reversal of the paging direction could be performed either by terminating the PAGE procedure after the first modified PAGE message, immediately followed by a new PAGE procedure initiated by the previously paged BT unit, or the paging direction could be immediately reversed (without termination) by letting the BT unit receiving the request for reversed paging direction send an FHS packet (with all parameters set as if the sender is the paging BT unit) to the BT unit sending the request. In both cases the respective procedure proceeds as a regular PAGE procedure.

Of course, the procedures described in this section may be used even if the paged BT unit is not a master unit. There may still be reasons for the paging BT unit to become a slave of the new piconet that will be formed.

The preferred procedure in this part of the solution is to indicate the request for reversal of the paging direction using one of the undefined bits in the FHS packet and immediately reversing the paging direction by letting the receiver of the first FHS packet return another FHS packet and then proceeding as a normal PAGE procedure

The invention is not necessarily limited to a Bluetooth system, although for a system to be applicable it has to have certain similar properties. A generalisation of the present invention would be to describe it as follows:

The first part:

In an ad-hoc networking system where the participating units use a neighbour discovery mechanism and can establish distinct, albeit dynamic, ad-hoc networks, an exchange is made during the neighbour discovery procedure of information about the respective units' status in existing ad-hoc networks (or other useful unit or network related information, e.g. number of units in the ad-hoc network, address(es) of other unit(s) in the ad-hoc network, clock value(s) (of the unit itself or of other unit(s) in the ad-hoc network), scheduling parameters, battery status, traffic parameters, priority parameters, etc.). The received information can then be used in the respective units when deciding which ad-hoc network(s) to join, how to join it/them and whether to try to establish (and with which other units) a new (or several new) ad-hoc network(s). The received information could also be used to facilitate reforming of existing ad-hoc network structures.

The second part:

During the establishment of an ad-hoc network, if the initiator of the establishment automatically gets a certain specific role in the ad-hoc network, e.g. master or slave, a mechanism is provided to let the initiating unit request from another unit that it takes over the role of initiator. This "mechanism" becomes either a new parameter in an existing message used in the establishment phase or a new message.

In Figure 7 can be seen a flowchart which provides an overview of how both the first part and second part of the present invention function together. A first BT unit sends 700 an INQUIRY message or messages. Any BT which receives this message will send an INQUIRY RESPONSE message back to the first BT unit which will then be received by the first BT unit. A second, third and fourth BT in this embodiment send an INQUIRY RESPONSE message to the first BT. This message will indicate that the BT sending the INQUIRY RESPONSE message is

either a slave unit in some piconet, as for the second and fourth BTs, or a master unit in some piconet, as for the third BT. The message from the second BT will be received 710 by the second BT as will the message from the third BT 720 and the fourth.

Of the second, third and fourth responding BTs, only the third responded that it was a master unit in some piconet. The first BT will choose 740 to connect to this second BT as a slave unit. It then sends 750 a PAGE message to this third BT unit which responds to the first BT unit which then receives 760 this response.

In order for the first BT unit to be able to connect to the third BT unit as a slave without using the master-slave switch we then continue according to the second part of the present invention. The first BT unit sends 770 an FHS packet to the third BT unit requesting a reversal of the paging direction. This FHS packet is sent by the third BT unit which is received 780 by the first BT unit, thereby reversing the paging direction. To conclude the procedure the first BT unit responds 790 to the FHS packet with its DAC which will then connect 795 the first BT unit to the third BT unit as a slave unit.

A slightly more detailed version of this procedure can also be seen in the flowchart in Figure 8.

The embodiments described above serve merely as illustration and not as limitation. It will be apparent to one of ordinary skill in the art that departures may be made from the embodiments described above without departing form the spirit and scope of the invention. The invention should not be regarded as being limited to the examples described, but should be regarded instead as being equal in scope to the following claims.

WHAT IS CLAIMED IS:

1) A method for the establishment of an ad-hoc system characterised wherein

the specific role of the unit which initiates connection of the establishment is transferred to another unit during the establishment phase.

2) The method of Claim 1 characterised wherein said ad-hoc system contains a master and at least one slave, a first ad-hoc system unit neighbouring said ad-hoc system, and said establishment further includes a method for said ad-hoc system unit to discover the status of other units in said ad-hoc system characterised by

the exchange of system-related information during the neighbour discovery procedure.

3) In a Bluetooth system comprising a first Bluetooth unit (BT) and at least one Bluetooth piconet containing a master and at least one slave, a method of discovering the status of the Bluetooth units in said at least one piconet comprising the steps of:

said first Bluetooth unit sending an INQUIRY message; and

said at least one Bluetooth unit in said at least one Bluetooth piconet responding to said first Bluetooth unit by sending an INQUIRY RESPONSE message comprising a Frequency Hop Synchronisation (FHS) packet;

characterised wherein

said FHS packet further includes information as to said responding Bluetooth unit's status in said at least one Bluetooth system.

4) The method of Claim 3 further characterised wherein

said FHS packet further includes information as to whether said responding BT unit is a master of said at least one piconet.

5) The method of Claim 3 further characterised wherein

said FHS packet further includes information as to whether said responding BT unit is a slave unit in at least one of said at least one piconets.

6) The method of Claims 3-5 further characterised wherein

said FHS packet further includes information as to at least one of the following: whether said responding BT unit is connected to at least one of said at least one piconet, whether said responding BT unit is a slave in at least one of said at least one piconet, whether said responding BT unit prefers to be a master or a slave after a subsequent PAGE procedure, the number of slaves in at least one of said at least one piconet, the BD_ADDR(s) of at least one master unit of said at least one piconet where said responding BT unit is a slave member, the clock value(s) of at least one master unit of said at least one piconet where said responding BT unit is a slave member, inter-piconet scheduling parameters of at least one BT unit (said at least one BT unit may or may not include said responding BT unit) that is connected to at least two piconets, the battery status of said responding BT unit, traffic parameters in at least one of said piconets or priority parameters.

7) The method of Claims 3-6 further characterised wherein

said information is encoded using at least one of two undefined bits in said FHS packet.

8) The method of Claim 7 further characterised wherein

one of said at least two undefined bits encodes whether said responding BT unit is a master of a piconet.

9) The method of Claim 7 further characterised wherein

one of said at least two undefined bits encodes whether said responding BT unit is a slave in at least one piconet.

10) The method of Claims 3-6 further characterised wherein

said information is encoded using the Class of Device field in said FHS packet.

11) The method of Claims 3-6 further characterised wherein

said information is encoded using the AM_ADDR field in said FHS packet.

12) The method of Claim 11 further characterised wherein

said AM_ADDR field is used to encode whether said responding BT, when subsequently paged, will want to connect to the paging unit as a slave or a master.

13) The method of Claims 3-6 further characterised wherein

said information is encoded using a combination of said undefined bits, said Class of Device field and said AM_ADDR field in said FHS packet.

14) The method of Claim 13 further characterised wherein

said AM_ADDR is used to encode the number of active slave units in the piconet for which said responding BT unit is a master.

15) The method of Claims 3-14 wherein said responding BT is a slave in a piconet further characterised wherein

said first BT sends a PAGE to said slave indicating said first BT's intent to retrieve the at least one address (BD_ADDR) for

the at least one master for said slave and said slave sending a PAGE RESPONSE message containing the requested at least one BD_ADDR.

16) The method of Claim 15 further characterised wherein

said PAGE RESPONSE includes at least one current clock value of said at least one master units of said responding BT unit.

17) The method of Claims 15 or 16 further characterised wherein

said PAGE RESPONSE further includes information as to at least one of the following: whether said responding BT unit is connected to at least one of said at least one piconet, whether said responding BT unit is a slave in at least one of said at least one piconet, whether said responding BT unit prefers to be a master or a slave after a subsequent PAGE procedure, the number of slaves in at least one of said at least one piconet, the BD_ADDR(s) of at least one master unit of said at least one piconet where said responding BT unit is a slave member, the clock value(s) of at least one master unit of said at least one piconet where said responding BT unit is a slave member, inter-piconet scheduling parameters of at least one BT unit (said at least one BT unit may or may not include said responding BT unit) that is connected to at least two piconets, the battery status of said responding BT unit, traffic parameters in at least one of said piconets or priority parameters.

18) In a Bluetooth system comprising a first Bluetooth unit (BT) and at least one Bluetooth piconet containing a master and at least one slave, a method of discovering the status of the Bluetooth units in said at least one piconet comprising the steps of:

said first Bluetooth unit sending an INQUIRY message; and

said at least one Bluetooth unit in said at least one Bluetooth piconet responding to said first Bluetooth unit by sending an INQUIRY RESPONSE message comprising a Frequency Hop Synchronisation (FHS) packet;

characterised wherein

said INQUIRY message contains a Dedicated Inquiry Access Code (DIAC) which is only responded to by master units.

19) In a Bluetooth system comprising a first Bluetooth unit (BT) and at least one Bluetooth piconet containing a master and at least one slave, a method of discovering the status of the Bluetooth units in said at least one piconet comprising the steps of:

said first Bluetooth unit sending an INQUIRY message; and

said at least one Bluetooth unit in said at least one Bluetooth piconet responding to said first Bluetooth unit by sending an INQUIRY RESPONSE message comprising a Frequency Hop Synchronisation (FHS) packet;

characterised wherein

said INQUIRY message contains a Dedicated Inquiry Access Code (DIAC) which is dedicated to, and will only be responded to, by one of the following:

- a BT unit being a slave unit in one and only one piconet,

- a BT unit being a slave unit in at least one piconet,

- a BT unit being a slave unit in more than one piconet,

- a BT unit being a slave unit in one or more piconets, but a master unit in none,

- a BT unit being a slave unit in one or more piconets and a master unit in one piconet,

- a BT unit being a master unit in one piconet, but a slave unit in none,

- a BT unit that is not connected to any piconet,

- a BT unit with low current traffic load, or

- a BT unit with high current traffic load.

20) The method of Claims 3-19 further characterised wherein

said INQUIRY message contains a Dedicated Inquiry Access Code (DIAC) which is only responded to by master units.

21) The method of Claims 3-19 further characterised wherein

said INQUIRY message contains a Dedicated Inquiry Access Code (DIAC) which is dedicated to, and will only be responded to, by one of the following:

- a BT unit being a slave unit in one and only one piconet,

- a BT unit being a slave unit in at least one piconet,

- a BT unit being a slave unit in more than one piconet,

- a BT unit being a slave unit in one or more piconets, but a master unit in none,

- a BT unit being a slave unit in one or more piconets and a master unit in one piconet,

- a BT unit being a master unit in one piconet, but a slave unit in none,

- a BT unit that is not connected to any piconet,

- a BT unit with low current traffic load,

- a BT unit with high current traffic load.

22) In a Bluetooth system comprising a first Bluetooth unit (BT) and at least one Bluetooth unit which is known to the first BT unit to be a master of a piconet, a method of connecting the first BT unit to this at least one piconet master as a slave unit comprising the steps of:

sending a PAGE message from said first BT to said master BT;

sending a PAGE RESPONSE from said master to said first BT; and

sending a Frequency Hop Synchronisation (FHS) packet from said first BT to said master;

characterised wherein

said FHS packet includes an indication that said first BT wants to reverse the paging direction from said master to said first BT.

23) The method of Claim 22 further characterised wherein

said reversal is performed by terminating said current PAGE procedure and initiating a new PAGE procedure from said master to said first BT.

24) The method of Claim 22 further characterised wherein

said reversal is performed by said master BT which receives said request for reversal sending an FHS packet to said first BT with all FHS parameters set as if the sender is the paging BT unit and said first BT responding with a packet including only said first BT's DAC, thereby concluding said reversed page procedure.

25) The method of Claims 22-24 where said paged BT unit does not accept said reversal of paging direction further characterised wherein

said paged BT unit responding to said FHS packet with a second FHS packet including the same indication of request for reversal of paging direction and said first BT unit receiving this second FHS packet choosing to either proceed with said PAGE procedure without reversing or abandoning said PAGE procedure.

26) The method of Claim 25 further characterised wherein

if said first BT unit chooses to proceed with said PAGE procedure it proceeds by restarting the PAGE procedure by sending a new initial PAGE message.

27) The method of Claim 25 further characterised wherein

if said first BT unit chooses to proceed with said PAGE procedure it proceeds by sending a third FHS message without an indication of request for reversal of paging direction.

28) In a Bluetooth system comprising a first Bluetooth unit (BT) and at least one Bluetooth piconet containing a master and at least one slave, a method of discovering the status of the Bluetooth units in said at least one piconet and connecting said first BT unit to said at least one piconet master as a slave comprising the steps of:

sending (700) an INQUIRY message from the first BT unit;

the first BT unit receiving (710) an INQUIRY response message from a second BT unit which is a slave unit in at least one piconet, said INQUIRY response message indicating that said second BT unit is a slave unit;

the first BT unit receiving (720) an INQUIRY response message from a third BT unit which is a master unit in at least one piconet, said INQUIRY response message indicating that said third BT unit is a master unit;

the first BT unit receiving (730) an INQUIRY response message from a fourth BT unit which is a slave unit in at least one piconet;

the first BT unit choosing (740) to connect to said third BT unit as a slave unit;

the first BT unit sending (750) a PAGE message to said third BT unit;

the first BT unit receiving (760) a response from said third BT unit;

the first BT unit sending (770) an FHS packet to the third BT unit requesting a reversal in paging direction;

the first BT unit receiving (780) an FHS packet from the third BT unit, thereby reversing the paging direction;

the first BT unit responding (790) to said FHS packet from said third BT unit with said first BT unit's DAC; and

the first BT unit connecting (795) to the third BT unit as a slave.

29) In a Bluetooth system comprising a first Bluetooth unit (BT) and at least one Bluetooth piconet containing a master and at least one slave, an apparatus for discovering the status of the Bluetooth units in said at least one piconet and connecting said first BT unit to said at least one piconet master as a slave comprising:

means for sending (700) an INQUIRY message from the first BT unit;

means for receiving (710) in the first BT unit an INQUIRY response message from a second BT unit which is a slave unit in at least one piconet, said INQUIRY response message indicating that said second BT unit is a slave unit;

means for receiving (720) in the first BT unit an INQUIRY response message from a third BT unit which is a master unit in at least one piconet, said INQUIRY response message indicating that said third BT unit is a master unit;

means for receiving (730) in the first BT unit an INQUIRY response message from a fourth BT unit which is a slave unit in at least one piconet;

means for the first BT unit to choose (740) to connect to said third BT unit as a slave unit;

means for sending (750) from the first BT unit a PAGE message to said third BT unit;

means for receiving (760) in the first BT unit a response from said third BT unit;

means for sending (770) from the first BT unit an FHS packet to the third BT unit requesting a reversal in paging direction;

means for receiving (780) in the first BT unit an FHS packet from the third BT unit, thereby reversing the paging direction;

means for responding (790) in the first BT unit to said FHS packet from said third BT unit with said first BT unit's DAC; and

means for connecting (795) the first BT unit to the third BT unit as a slave.

30. A computer program product directly loadable into the internal memory of a digital computer, comprising software code portions for performing the steps of any of the above claims when said product is run on a computer.

31. A computer program product stored on a computer usable medium, comprising readable program means for causing a computer to control the execution of the steps in any of Claims 1-28.

Abstract

The invention is mainly related to the problem of forming ad-hoc wireless networks and more particularly to the wireless technology Bluetooth and how a Bluetooth device may best discover masters in existing piconets and connect as a slave to those masters without having to use the master-slave switch. When a Bluetooth (BT) device moves into the neighbourhood of an existing piconet it may want to communicate with the BT units connected to that piconet by joining that piconet as a slave. Under the current Bluetooth specification the BT unit would have to rely on either "wait and hope" or "chance connection" methods of the specification. The method of the invention provides additional information about the responding BT unit's status in the existing piconet(s) which facilitates the decision as to which BT unit to connect to. A new mechanism is introduced whereby the initially inquiring and paging BT unit may become a slave unit in a newly formed piconet or in an already existing piconet. (Fig. 7)

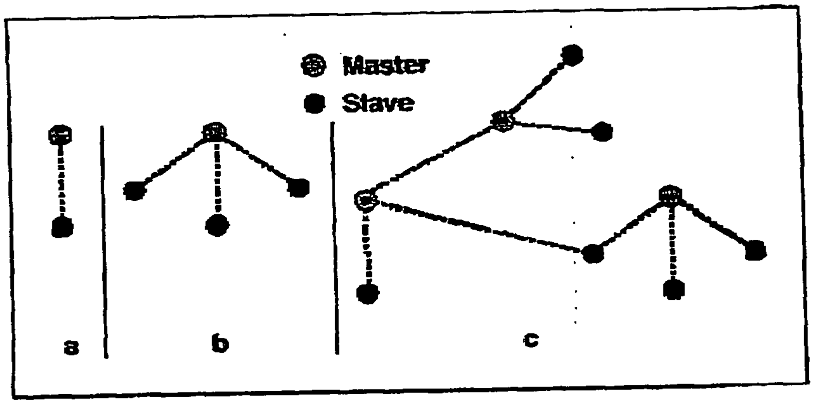

Fig. 1

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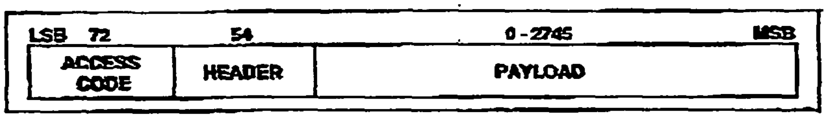

Fig. 2

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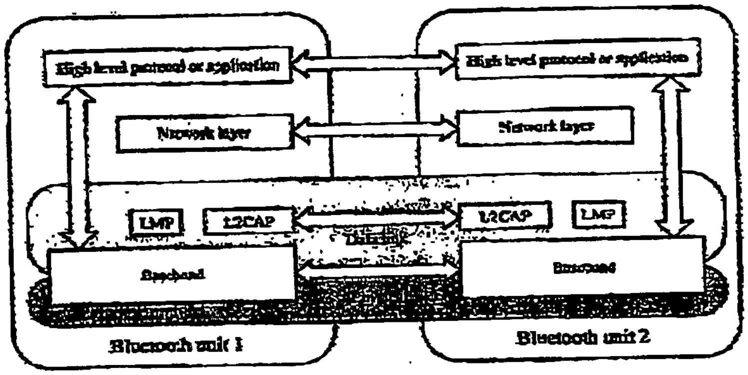

The Bluetooth protocol layers. The Baseband, LMP and L2CAP represent existing Bluetooth specific protocols, the "High level protocol or application" represents protocols that may or may not be Bluetooth specific while the Network layer is currently not specified in the Bluetooth standard.

Fig. 3

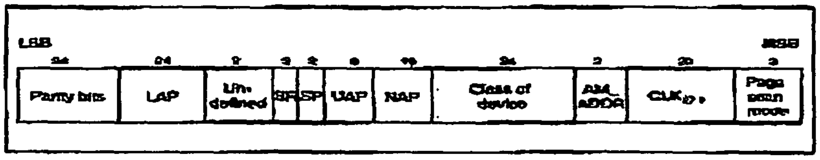

Fig. 4

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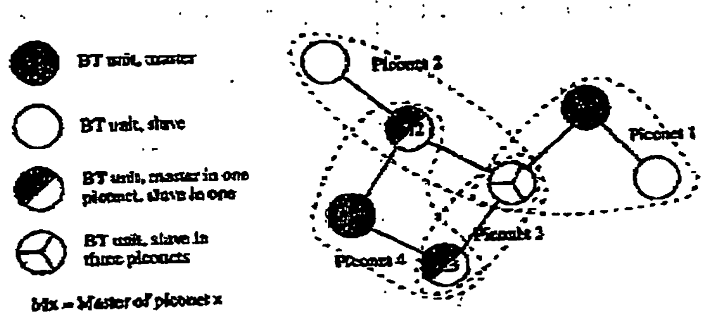
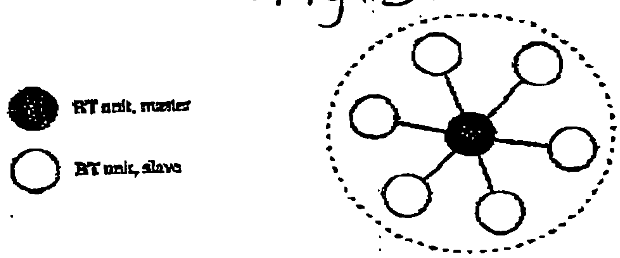


Suboptimal piconet and scatternet structure.

Fig. 5



Optimal piconet structure.

Fig. 6

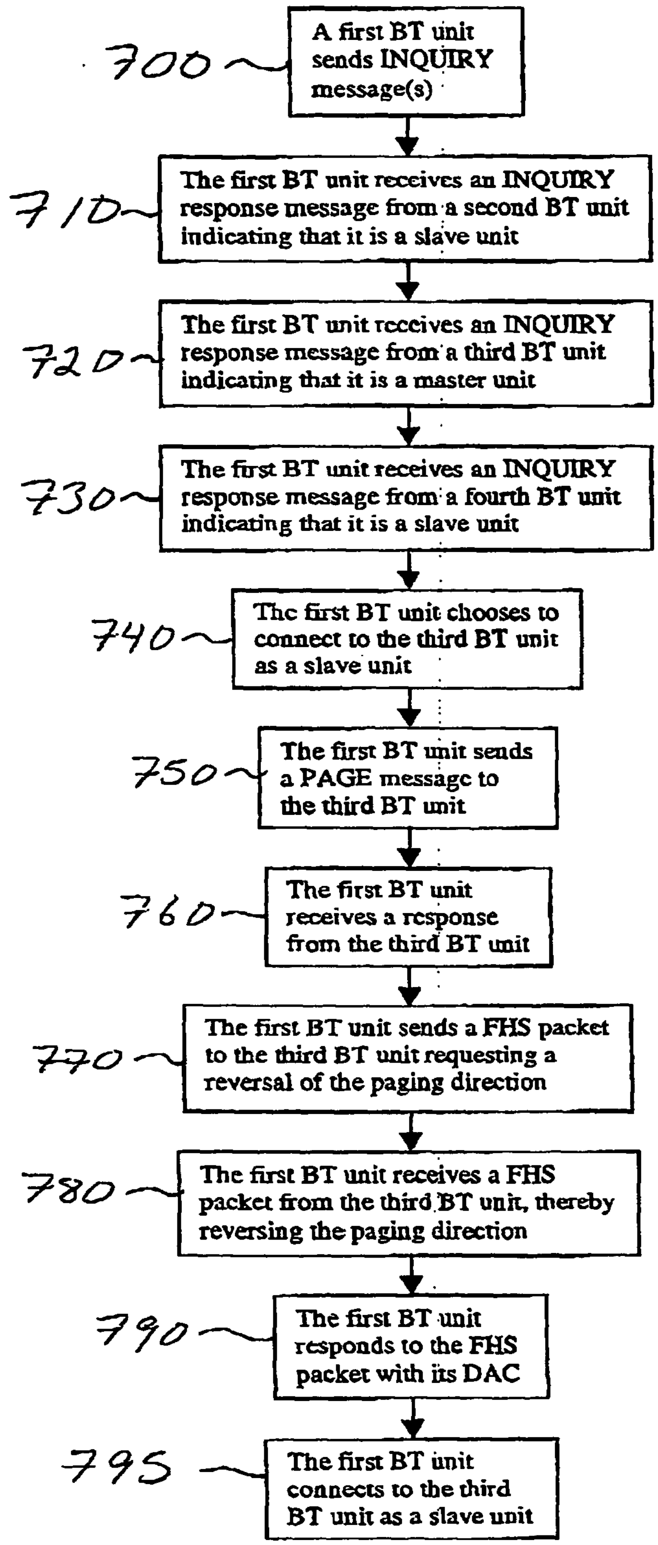

700
A first BT unit sends INQUIRY message(s)
710
The first BT unit receives an INQUIRY response message from a second BT unit indicating that it is a slave unit
720
The first BT unit receives an INQUIRY response message from a third BT unit indicating that it is a master unit
730
The first BT unit receives an INQUIRY response message from a fourth BT unit indicating that it is a slave unit
740
The first BT unit chooses to connect to the third BT unit as a slave unit
750
The first BT unit sends a PAGE message to the third BT unit
760
The first BT unit receives a response from the third BT unit
770
The first BT unit sends a FHS packet to the third BT unit requesting a reversal of the paging direction
780
The first BT unit receives a FHS packet from the third BT unit, thereby reversing the paging direction
790
The first BT unit responds to the FHS packet with its DAC
795
The first BT unit connects to the third BT unit as a slave unit

Fig. 7

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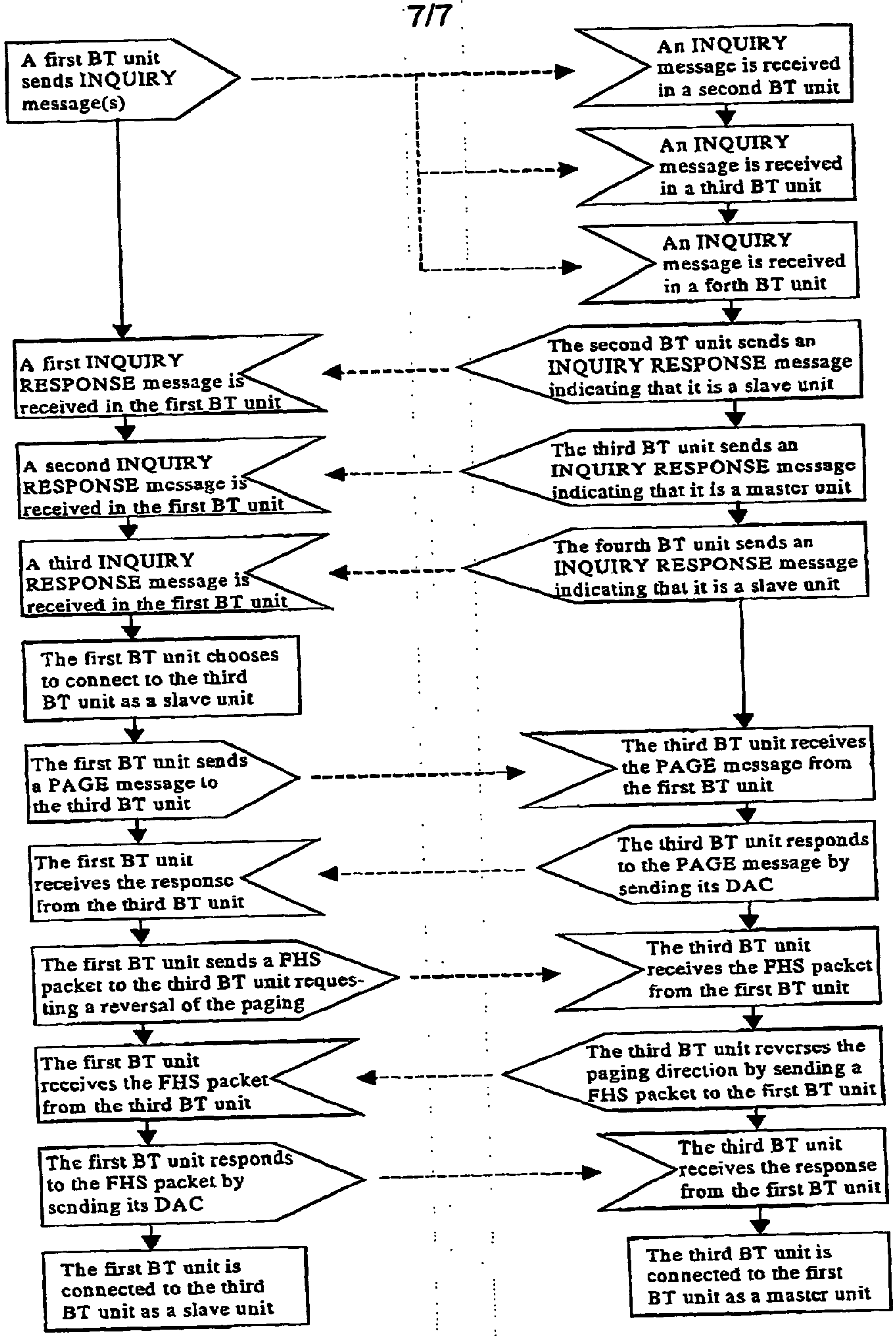
A first BT unit sends INQUIRY message(s)
An INQUIRY message is received in a second BT unit
An INQUIRY message is received in a third BT unit
An INQUIRY message is received in a forth BT unit
The second BT unit sends an INQUIRY RESPONSE message indicating that it is a slave unit
A first INQUIRY RESPONSE message is received in the first BT unit
The third BT unit sends an INQUIRY RESPONSE message indicating that it is a master unit
A second INQUIRY RESPONSE message is received in the first BT unit
The fourth BT unit sends an INQUIRY RESPONSE message indicating that it is a slave unit
A third INQUIRY RESPONSE message is received in the first BT unit
The first BT unit chooses to connect to the third BT unit as a slave unit
The first BT unit sends a PAGE message to the third BT unit
The third BT unit receives the PAGE message from the first BT unit
The third BT unit responds to the PAGE message by sending its DAC
The first BT unit receives the response from the third BT unit
The first BT unit sends a FHS packet to the third BT unit requesting a reversal of the paging
The third BT unit receives the FHS packet from the first BT unit
The third BT unit reverses the paging direction by sending a FHS packet to the first BT unit
The first BT unit receives the FHS packet from the third BT unit
The first BT unit responds to the FHS packet by sending its DAC
The third BT unit receives the response from the first BT unit
The first BT unit is connected to the third BT unit as a slave unit
The third BT unit is connected to the first BT unit as a master unit

Fig. 8